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Funding and Strategic Alignment Guidance for Infusing Small Business Innovation Research Technology Into Aeronautics Research Mission Directorate Projects at NASA Glenn Research Center for 2015

Hung D. Nguyen, Gynelle C. Steele, and Jessica R. Morris
Glenn Research Center, Cleveland, Ohio

September 2015

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Abstract

This report is intended to help NASA program and project managers incorporate Small Business Innovation Research/Small Business Technology Transfer (SBIR)/(STTR) technologies into NASA Aeronautics Research Mission Directorate (ARMD) projects. Other Government and commercial projects managers can also find this useful.

Introduction

Incorporating Small Business Innovation Research (SBIR)-developed technology into NASA projects is important, especially given the Agency's limited resources for technology development. The program's original intention was for technologies that had completed Phase II to be ready for integration into NASA programs, however, in many cases there is a gap between Technology Readiness Levels (TRLs) 5 and 6 that needs to be closed.

After SBIR Phase II projects are completed, the technology is evaluated against various parameters and a TRL rating is assigned. Most programs tend to adopt more mature technologies—at least TRL 6 to reduce the risk to the mission rather than adopt TRLs between 3 and 5 because those technologies are perceived as too risky. The gap between TRLs 5 and 6 is often called the "Valley of Death," (Fig. 1) and historically it has been difficult to close because of a lack of funding support from programs. Several papers have already suggested remedies on how to close the gap (Refs. 1 to 4).

SBIR Solicitation Process

Understanding how the SBIR solicitation process works should help small businesses and Aeronautics Research Mission Directorate (ARMD) project managers form partnerships to incorporate SBIR technologies into NASA programs and projects. For example, when ARMD program managers identify specific SBIR subtopics that are likely to generate technologies that could apply to their programs or projects, the SBIR office would provide information about previously developed technologies that could be incorporated into their work. Small business PIs would also benefit from understanding NASA program and project needs, thus increasing the likelihood that the technologies they developed will be infused into ARMD projects. The fiscal year (FY) 2015 and 2014 solicitations are posted at http://sbir.gsfc.nasa.gov/solicitations.

Integrating SBIR-developed technology into NASA programs and projects is important, especially given the Agency's limited resources for technology development. The SBIR program's original intent was for technologies that had completed Phase II to be ready for integration into NASA programs. Now the SBIR program supports its small business partners with three post-Phase II options that focus on creating opportunities for commercialization as well as technology integration. The Phase II Enhancement

* Lewis' Educational and Research Collaborative Internship Project (LERCIP).

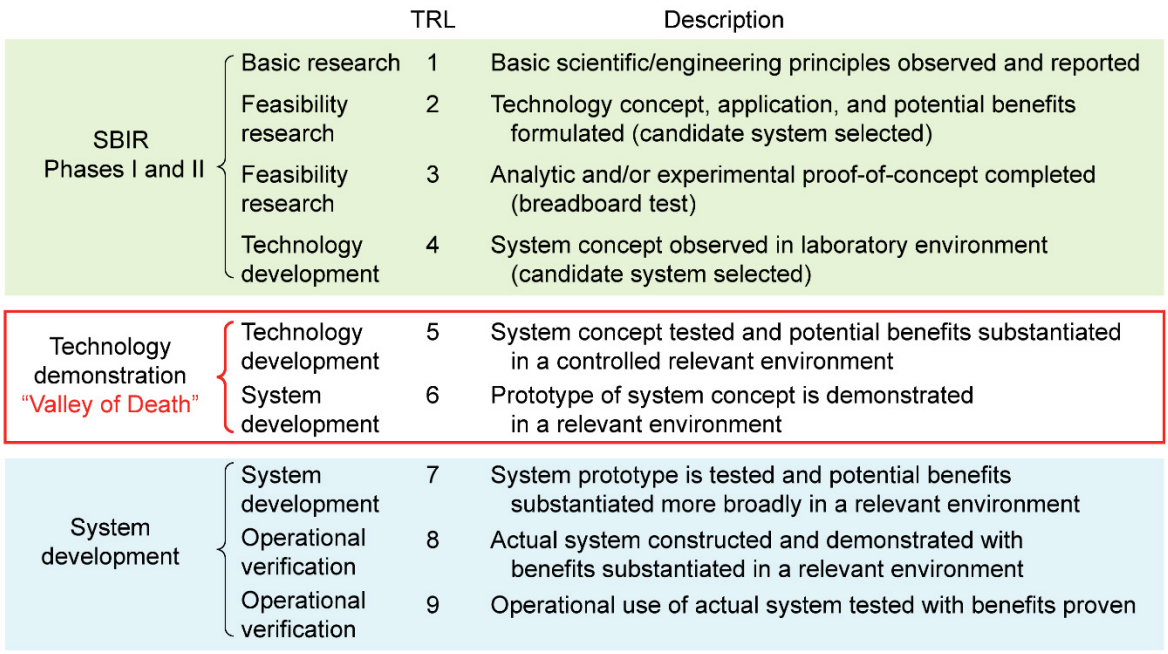

Figure 1.—Technology Readiness Levels (TRLs).

(Phase II-E), Phase II Expanded (Phase II-X), and Commercialization Readiness Pilot (CRP) options also provide opportunities for Phase II technologies to be integrated and tested in the NASA system platform or in the space environment.

The three post-Phase II options, which typically last between 6 and 36 months, create more opportunities to advance technology maturity, reduce associated risks, and increase the likelihood for integrating technology into NASA, Department of Defense (DoD), or external entity programs.

- Phase II-E: This option advances Phase II innovations by extending existing Phase II contracts. Under Phase II-E extensions, NASA SBIR will match, investments in technology development that small businesses secure from eligible non-NASA SBIR third parties on a dollar-for-dollar basis. The minimum matching investment is $25,000 and the maximum is $150,000, extending projects by 6 to 12 months.
- Phase II-X: This option establishes a strong and direct partnership between the SBIR program and NASA programs and projects undertaking new technology development. Under Phase II-X expansions, NASA SBIR will double the funding that small businesses secure from non-SBIR NASA programs or projects. The minimum investment that NASA SBIR will double is $75,000 and the maximum is $250,000. Expanded projects last between 12 and 24 months.
- The Commercialization Readiness Program (CRP): This option accelerates transition of SBIR-developed technologies into NASA applications. Projects that request SBIR funding under the CRP option must (1) involve a technology that entered into either a Phase I or Phase II contract and (2) identify how more SBIR funding would accelerate development in response to NASA program or project needs. The minimum matching investment is $100,000 and the maximum is $1.5 million, extending projects by 24 to 36 months.

Table 1 summarizes the three post-Phase II options.

TABLE 1.—NASA SBIR POST-PHASE II FUNDING OPTIONS

Criteria	Phase II-E	Phase II-X[a]	CRP
Purpose	Advance SBIR technology by extending current Phase II contracts	Establish partnerships between NASA programs and projects and non-SBIR companies	Accelerate transition of SBIR-developed technologies into NASA applications
Funding source	Any eligible non-NASA SBIR third party	NASA program or project	Either eligible NASA program or project or non-NASA SBIR third party
Minimum, dollars	$25,000	$75,000	$0
Maximum, dollars	$150,000	$250,000	$0
SBIR match	1:1	2:1	Up to $1,500,000
Performance period, months	6 to 12	12 to 24	24 to 36

[a]Beginning in FY 2012

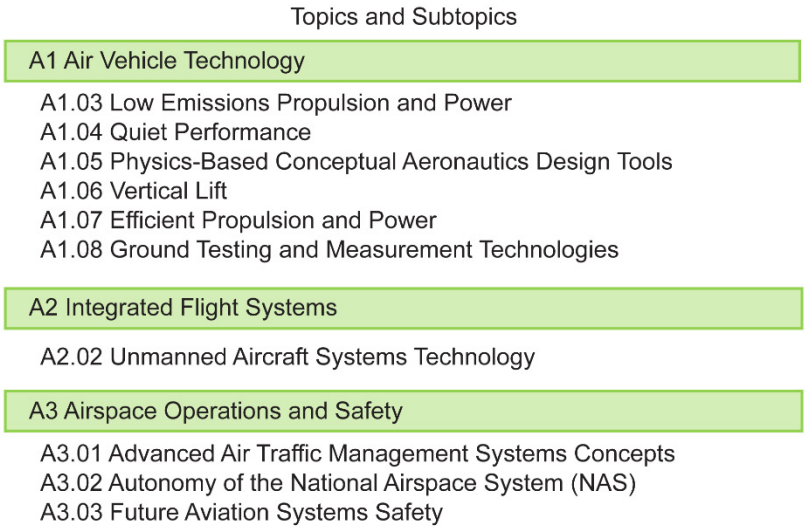

Figure 2.—FY 2015 Phase I SBIR ARMD topics and subtopics that involve GRC.

Fiscal Year 2015 Phase I GRC SBIR Subtopic Summaries

Topics and subtopics for all directorates are listed in Chapter 9 of the FY15 Phase I SBIR solicitation. ARMD topics and subtopics that involve GRC are shown in Figure 2 and ARMD solicitation descriptions follow.

A1.03 Low Emissions Propulsion and Power

Supports electric propulsion of transport aircraft, including turboelectric propulsion (turbine prime mover with electric distribution of power to propulsors) and various hybrid electric concepts, such as gas turbine engine and battery combinations. Turboelectric propulsion for transport aircraft applications will require components with high specific power (hp/lb or kW/kg) and high efficiency, and cryogenic and superconducting components will likely be required. The cryogenic components of interest include fully superconducting generators and motors (i.e., superconducting stators as well as rotors), cryogenic inverters and active rectifiers, and cryocoolers.

A1.04 Quiet Performance

Improvements in noise prediction, acoustic and relevant flow field measurement methods, noise propagation and noise control are needed for subsonic, transonic and supersonic vehicles targeted specifically at airframe noise sources and the noise sources due to the aerodynamic and acoustic interaction of airframe and engines. Innovative source identification techniques for airframe (e.g., landing gear, high lift systems) noise sources, including turbulence details related to flow-induced noise typical of separated flow regions, vortices, shear layers, etc.

A1.05 Physics-Based Conceptual Aeronautics Design Tools

Investigates the potential of advanced, innovative propulsion and aircraft concepts to improve fuel efficiency and reduce the environmental footprint of future generations of commercial transports across the breadth of the flight speed regimes. Propulsion systems such as open rotors and hybrid-electric propulsion, are viewed as potential options for helping meet aggressive, long range (i.e., 'N+3' timeframe) emission reduction targets. Accurate representation of the propulsion system is critical in confidently assessing the potential of a concept. Conceptual design and analysis of unconventional propulsion concepts and technologies is used for technology portfolio investment planning, development of advanced concepts to provide technology pull and independent technical assessment of new concepts.

A1.06 Vertical Lift

The use of small vertical lift UAVs has increased in recent times with many civilian missions being proposed, including autonomous surveillance, mapping, etc. Much of the current research associated with these vehicles has been in the areas of electric propulsion, batteries, small sensors and autonomous control laws, while very little attention has been paid to their acoustic signature. The generation and propagation of noise associated with this small class of vertical lift UAVs are not well understood and validated prediction tools do not currently exist. The objective of a proposed effort would be to develop tools for the modeling and prediction of the high frequency acoustics for small vertical lift UAVs, such as quad-copters, coaxials, ducted fan rotors, etc.

A1.07 Efficient Propulsion and Power

Focuses on propulsion controls and dynamics. Typical current operating engine control logic is designed using SISO (Single Input Single Output) PI (Proportional+Integral) control. The control logic is designed to provide minimum guaranteed performance while maintaining adequate safety margins throughout the engine operating life. Additionally, the control logic indirectly provides control of variables of interest such as Thrust, Stall Margin, etc. since these variables cannot be measured or are not measured in flight because of restrictions on sensor cost/placement/reliability, etc. to develop all aspects of control systems to enable safe operation of low emissions combustors throughout the engine operating envelope. Low emission combustors are prone to thermo-acoustic instabilities. So far NASA research in this area has focused on modulating the main or pilot fuel flow to suppress such instability. Advanced, ultra-low emissions combustors utilize multi-point (multi-location) injection to achieve a homogeneous, lean fuel/air mixture.

A1.08 Ground Testing and Measurement Technologies

Develops innovative tools and technologies that enhance testing and measurement capabilities, improve ground test resource utilization and efficiency, and provide capability sustainment. Where

possible, the tools and technologies should be applicable for the broad national scope of government, commercial, and university capabilities.

A2.02 Unmanned Aircraft Systems Technology

Unmanned Aircraft Systems (UAS) offer advantages over manned aircraft for applications which are dangerous to humans, long in duration, require great precision, and require quick reaction. Examples of such applications include remote sensing, disaster response, delivery of goods, agricultural support, and many other known and yet to be discovered. In addition, the future of UAS promises great economic and operational advantages by requiring less human participation, less human training, an ability to take-off and land at any location, and the ability to react to dynamic situations.

Fiscal Year 2014 Phase II GRC SBIR Subtopics Summary

Topics and subtopics for all directorates are listed in Chapter 9 of the FY14 Phase II SBIR solicitation. ARMD topics and subtopics that involve GRC are shown in Figure 3 and ARMD solicitation descriptions follow.

A1.01 Aviation External Hazard Sensor Technologies

Explores new and improved sensors and sensor systems for the detection and monitoring of hazards to aircraft before they are encountered. Approaches that use multiple sensors in combination to improve hazard detection and quantification of hazard levels are also of interest. With regard to hazardous lightning conditions, the emphasis is not on remote detection, but rather on developing systems that make aircraft more robust in a lightning environment or provide in-flight damage assessment or other hazard mitigating benefits. The scope of this subtopic does not include human factors and focused development of human interfaces, including displays and alerts. Primary emphasis is on airborne applications, but in some cases the development of ground-based sensor technology may be supported.

Figure 3.—FY 2014 Phase II SBIR ARMD topics and subtopics that involve GRC.

A1.02 Inflight Icing Hazard Mitigation Technology

Prevents hazardous in-flight conditions by addressing detection, measurement, and/or the mitigation of the hazards of flight into super-cooled liquid water clouds and flight into regions of high mass concentrations of ice crystal. Measurement and detection can include measurement of the phase (ice or liquid), measurement of the mass of the droplets, or 3-D measurements of ice density.

A2.01 Unmanned Aircraft System Integration in the National Airspace System

Unmanned Aircraft Systems (UAS) are needed to fly in the national Airspace System (NAS) to perform missions for the National Security and Defense, Emergency Management, Science, and commercial applications. Technology needs to be developed in order to reduce technical barriers for integrating UAS into the NAS. Currently, five subprojects for this category include: separation assurance/sense and avoid interoperability, communications, human systems integration, certification, and integrated test and evaluation.

A3.02 Quiet Performance

Improve noise prediction, acoustic and relevant flow field measurement methods, noise propagation, and noise control for subsonic, transonic, and supersonic vehicles, specifically targeting airframe noise sources and the noise sources due to the aerodynamic and acoustic interaction of the airframe and engines.

A3.03 Low Emissions/Clean Power

Achieves lower emissions and discover new paths to cleaner power for future air vehicles, which will be required to operate under more stringent regulations for gaseous and particulate emissions. The foundation for more efficient vehicles will be based on low emissions combustion processes which require very rapid mixing of the fuel and air with minimum pressure loss to achieve complete combustion in the smallest volume.

A3.05 Physics-Based Conceptual Design Tools

Investigates the potential of advanced, innovative propulsion and aircraft concepts to improve fuel efficiency and reduce the environmental footprint of future generations of commercial transports across the subsonic and supersonic flight regimes. Conceptual design and analysis of unconventional vehicle concepts and technologies is used for technology portfolio investment planning, development of advanced concepts to provide technology pull, and independent technical assessment of new concepts.

A3.06 Rotorcraft

Develops technologies and tools to overcome barriers for rotary wing vehicles, including noise and carbon emissions. Noise technologies predict, measure, and characterize noise associated with vertical lift UAVs. To address the emissions problem, all-electric and hybrid electric propulsion systems should be developed to reduce the carbon emissions and fuel consumption.

A3.07 Propulsion Efficiency-Propulsion Materials and Structures

Conducts novel research in materials and structures that enhance aircraft propulsion efficiency by reducing vehicle weight, fuel consumption, and increasing component durability/life. Research includes new materials such as high-temperature metals, alloys, ceramics, polymers, and their composites. Material systems and their interactions with harsh environmental conditions are of particular importance to develop more advanced materials for future systems.

A4.01 Ground Test Techniques and Measurement Technologies

Ground-based testing resources emphasize the technological need to improve wind tunnel utilization. Develops innovative tools/technologies that enhance testing and measurement capabilities, improves ground test resource utilization and efficiency, and provides capability sustainment.

Phase I and II Contract Awards

The number of Phase I and II contracts associated with ARMD are summarized in Tables 2 and 3.

TABLE 2.—FISCAL YEAR 2015 PHASE I CONTRACT AWARDS ASSOCIATED WITH THE AERONAUTICS RESEARCH MISSION DIRECTORATE

Subtopic[a]	Awards
A1.03 Low Emissions Propulsion and Power	3
A1.04 Quiet Performance	3
A1.05 Physics-Based Conceptual Aeronautics Design Tools	3
A1.06 Vertical Lift	2
A1.07 Efficient Propulsion and Power	2
A1.08 Ground Testing and Measurement Technologies	4
A2.02 Unmanned Aircraft Systems Technology	5

[a]See Appendix A for abstracts.

TABLE 3.—FISCAL YEAR 2014 PHASE II CONTRACT AWARDS ASSOCIATED WITH THE AERONAUTICS RESEARCH MISSION DIRECTORATE

Subtopic[a]	Awards
A2.01 Unmanned Aircraft Systems (UAS) Integration in the National Airspace System	6
A3.02 Quiet Performance	1
A3.03 Low Emission/Clean Power	1
A3.05 Physics-Based Design Tools	1
A3.06 Rotorcraft	2
A3.07 Propulsion Efficiency–Propulsion Materials and Structures	2
A4.01 Ground Test Techniques and Measurement Technologies	4

[a]See Appendix B for abstracts.

ARMD Program and Project Summaries

FY15 and FY14 ARMD topics and subtopics strategically align with ARMD programs and projects, and support the directorate's current needs and objectives. To help small business principal investigators (PIs) and ARMD project managers, it is important to understand how the SBIR subtopics are mapped to ARMD programs and projects for FY15 and FY14, respectively, as shown in Figures 4 and 5. ARMD program and project descriptions follow.

Topics and Subtopics	ARMD Programs and Projects
A1 Air Vehicle Technology	
A1.03 Low Emissions Propulsion and Power	Advanced Air Transportation Technology Project
A1.04 Quiet Performance	Airspace Operations and Safety Program Transformative Aeronautics Concepts Program
A1.05 Physics-Based Conceptual Aeronautics Design Tools	Advanced Air Transportation Technology Project Advanced Air Vehicle Program Commercial Supersonic Technology Project Environmentally Responsible Aviation Program Transformative Aeronautics Concepts Program
A1.06 Vertical Lift	Revolutionary Vertical Lift Technologies Project
A1.07 Efficient Propulsion and Power	Advanced Air Transportation Technology Project Advanced Air Vehicle Program Commercial Supersonic Technology Project Transformational Tools and Technologies Project Transformative Aeronautics Concepts Program
A1.08 Ground Testing and Measurement Technologies	Aeronautics Evaluation and Test Capabilities Project
A2 Integrated Flight Systems	
A2.02 Unmanned Aircraft Systems Technology	Airspace Operations and Safety Program Integrated Aviation System Project SMART-NAS Test-bed for Safe, Trajectory-Based Operations Projects Space Communications and Navigation Program Unmanned Aircraft Systems Integration Project

Figure 4.—FY 2015 Phase I SBIR ARMD subtopics that involve GRC mapped to ARMD programs and projects.

Figure 5.—FY 2014 Phase I SBIR ARMD subtopics that involve GRC mapped to ARMD programs and projects.

Advanced Air Vehicle Program

More environmentally friendly next-generation fixed-wing and vertical lift aircraft will be needed as both domestic and international air transportation growth accelerates. The Advanced Air Vehicle Program studies, evaluates, and develops technologies and capabilities that can be integrated into these aircraft systems as well as exploring far-future concepts that hold promise for revolutionary improvements to air travel.

Advanced Air Transportation Technology Project

Explores and develops technologies for advanced fixed-wing transport aircraft with revolutionary energy efficiency. These technologies are critical to reduce the environmental impact of aviation as the industry continues to grow. Advanced Air Transportation Technologies studies focus on the future and

target vehicles that are three generations beyond the current state of the art that require mature technology solutions in the 2025 to 2035 timeframe.

Aeronautics Evaluation and Test Capabilities Project

Sets the strategic direction for NASA's versatile and comprehensive portfolio of ground test aeronautics research capabilities. Its integrated approach to asset planning, use, and management will consider the complementary high-end computing capabilities necessary for advanced analyses in conjunction with the ground experimentation capabilities.

Airspace Operations and Safety Program

The Airspace Operations and Safety Program creates technologies to help NextGen fulfill its promise by working with the Federal Aviation Administration, industry, and academic partners to develop NextGen technologies to improve the intrinsic safety of current and future aircraft.

Commercial Supersonic Technology Project

Develops tools, technologies, and methods to help eliminate barriers to practical commercial supersonic flight: sonic boom, fuel efficiency, airport community noise, high-altitude emissions, structural weight, and flexibility, and airspace operations. Focuses mainly on sonic boom reduction methods and approaches.

Convergent Aeronautics Solutions Project

Merges traditional aeronautics disciplines with advancements driven by the non-aeronautics world to improve capabilities in commercial aviation. CAS teams conduct initial feasibility studies, perform experiments, try out new ideas, identify failures, and then review whether developed solutions have met their goals and whether they are feasible options in the real world.

Environmentally Responsible Aviation Project

Explores and documents the feasibility, benefits, and technical risk of vehicle concepts and enabling technologies to reduce aviation's impact on the environment. Assesses new vehicle concepts and enabling technologies through system-level experimentation to simultaneously reduce fuel burn, noise, and emissions.

Integrated Aviation System Program

The Integrated Aviation System Program conducts flightoriented, integrated, system-level research and technology development that supports the flight research needs across the ARMD strategies, programs, and projects. The IASP focuses on highly complex flight tests and related experiments.

Revolutionary Vertical Lift Technologies Project

Improves unique vertical capabilities by reducing noise and improving safety and fuel efficiency. RVLT research develops tools, technologies, and concepts that overcome performance barriers. These new technologies increase speed, range, and payload and decrease noise, vibration, fuel burn, and emissions by using improved computer-based prediction methods.

Space Communications and Navigation Program

The Space Communication and Navigation Program builds and maintains a scalable integrated mission support infrastructure that can accommodate new and changing technologies, while providing comprehensive, robust, cost-effective, and exponentially higher data rate space communications services to support NASA's science, space operations, and exploration missions.

SMART-NAS Testbed for Safe, Trajectory-Based Operations Project

The SMART-NAS project develops an air traffic management simulation capability to integrate alternative concepts, technologies, and architectures into the NAS. Simulations will take actual operational input from the NAS by employing advanced prognostics, data mining, and data analytics for enhanced decision-making and system assessments.

Transformational Tools and Technologies Project

Develops new computer-based tools, models, and associated scientific knowledge that will provide first-of-a-kind capabilities to analyze, understand, and predict performance for a wide variety of aviation concepts. Examples of research areas include predicting flow around vehicles and improving the understanding of strong and lightweight materials for aviation.

Transformative Aeronautics Concepts Program

The Transformative Aeronautics Concepts Program cultivates multidisciplinary, innovative concepts to transform aviation. Although TACP focuses on sharply focused research, the program provides flexibility for innovators to explore technology feasibility and provide the knowledge base for radical transformation. The program solicits and encourages revolutionary concepts, creates the environment for researchers to experiment with new ideas, performs ground and small-scale flight tests, allows failures and learns from them, and drives rapid turnover into potential future concepts.

Unmanned Aircraft Systems Integration in National Airspace System Project

Integrating UAS in the NAS project will provide research findings to reduce technical barriers associated with integrating UAS into the NAS. The barriers include a lack of sense-and-avoid concepts and technologies that can operate within the NAS, robust communication technologies, robust human systems integration, and standardized safety and certification guidelines.

Unmanned Aircraft Systems Traffic Management Project

There is a compelling need to regulate civilian UAS air traffic to avoid collisions and ensure safety. The UTM project enables safe and efficient low altitude airspace operations by providing services such as airspace design, corridors, dynamic geofencing, preventing severe weather, wind, and terrain damage, congestion management, route planning and re-routing, separation management, sequencing and spacing, and contingency management.

Appendix A.—Fiscal Year 2015 Phase I Contract Abstracts

A1.03-9122 Cryogenic and Non-Cryogenic Hybrid Electric Distributed Propulsion with Integration of Airframe and Thermal Systems to Analyze Technology Influence

A design iteration of ESAero's ECO-150 split wing turboelectric distributed propulsion (TeDP) concept is proposed to incorporate recent lessons learned in synergistic configuration opportunities, propulsion and thermal management system research and tool development, and aeropropulsive benefits reported by Lockheed Martin. Non-cryogenic and cryogenic/superconducting components will be included in three separate propulsion system architectures. Detailed configuration, aerodynamics, performance, and mission analysis will complement the effort, culminating in three flagship TeDP or hybrid electric distributed propulsion (HEDP) concepts which embody the propulsion-airframe-thermal integration (PATI) paradigm. A 2D and 3D CFD evaluation of the integrated propulsor will validate the physics-based aerodynamics and propulsor analysis tools.

A1.03-9200 High Performance Carbon Nanotube Based Conductors

This proposal is for the development of conductors with improved electrical conductivity and/or ampacity from that of copper or aluminum. Copper is presently the conductor of choice, based on high performance, low cost, and ease of use. However, increasing demands for power and data push the need for more capacity. Thus, the development of a commercial, low-cost, light-weight, high conductivity wire is an important objective to improve energy efficiency and reduce the weight/amp of power. We propose the development of a carbon nanotube (CNT) metal-based current carrying composite. We will focus on CNT additions to two base metals, copper and aluminum, in order to develop composites that have a high density of CNTs. Our objective is to develop methods to functionalize low resistance connections between CNTs. Our focus will demonstrate methods of improvement in Phase I, and optimization and fabrication of long length wires in Phase II.

A1.03-9346 A New Cryocooler for MgB2 Superconducting Systems in Turboelectric Aircraft

Turboelectric aircraft with gas turbines driving electric generators connected to electric propulsion motors have the potential to transform the aircraft design space by decoupling power generation from propulsion. Resulting aircraft designs such as blended-wing bodies with distributed propulsion can provide large reductions in emissions, fuel burn, and noise required to make air transportation growth projections sustainable. The power density requirements for these electric machines can only be achieved with superconductors, which in turn require lightweight, high-capacity cryocoolers. Here, we propose to extend the temperature range of our cryocooler with an innovative new cycle concept to provide cooling to 15 K for MgB2 superconductors. In Phase I of this project, we will evaluate the performance advantages of our concept through modeling and preliminary component designs. In Phase II, we will fabricate and test the highest-risk components to bring the overall TRL to 4. In Phase III, we will build and test a complete cryocooler to support extended performance testing with MgB2 systems

A1.04-9175 Shape Memory Alloy Adaptive Structures

Demonstrates and scales up an innovative manufacturing process that yields aerospace grade shape memory alloy (SMA) solids and periodic cellular structures. Bulk-sized SMA components and structures

are extremely difficult to fabricate as castings due to the compositional sensitivity of these alloys. Remelting also leads to brittleness from the presence of deleterious phases and precipitates that form upon metal solidification. For cost effectiveness, structural integrity, and shape memory and/or superelastic behavior, SMA castings with the requisite composition-microstructure-properties are needed and will be developed in this work.

A1.04-9178 Adjoint Techniques and Acoustic Three Zone Method for the Accurate Design of Low Boom Maneuvers (ATAtZM-DLBM)

Under this collaborative effort, Creative Aero Engineering Solutions (CAES) and its partner, Wyle Laboratories, will integrate within our MDO framework the latest development of the three zone method, which is expected to eliminate the need for far-field results beyond 25 spans that typical Sonic-Boom prediction two-zone methods currently use. CAES will use the adjoint solution of the near-field pressure functional of the flowfield (more specifically sonic boom related functionals) to create new design variables, which will better characterize the design space more accurately and allow for more efficient low-boom configuration design. Subsequently, a similar methodology can be utilized for trajectory optimization (i.e. avoidance of focused booms at certain locations) during climb and descent of typical supersonic aircraft.

A1.04-9214 Interferometric Correlator for Acoustic Radiation and Underlying Structural Vibration (ICARUSV)

Proposes an optical non-contact sensor fusion concept which, for the first time, enables direct capture and observation of full-field non-stationary dynamic structural intensity (DSI) and unsteady radiated sound fields or transient flow fields around the structure of interest. DSI depicts the flow of energy in a structure and provides an unambiguous identification of structural noise sources and sinks. Additionally, the ability to capture and correlate the acoustic/flow field data with the structure borne intensity offers an unprecedented and rapid diagnostic capability for noise source characterization and evaluation of noise abatement systems.

A1.05-9104 Physics-Based Aeroanalysis Methods for Open Rotor Conceptual Design

Operating costs and fossil fuel consumption of civil transports can be reduced through use of efficient counter rotating open rotor (CROR) propulsion systems. A blend of physics-based, low- and mid-fidelity tools featuring rapid turnaround time and ease of setup can provide this capability; implementation represents a serious technical challenge, though, and there is a high premium on developing tools that are both sufficiently accurate to capture current technology performance metrics while permitting the rapid re-calculations necessary for design trades. The proposed approach centers on a blend of enhanced features and novel departures for two complementary aeroanalysis methods: an evolved version of an established subsonic lifting surface free wake model for propellers as a fast, 'low-fidelity' tool; and a more computationally intensive, fully compressible Cartesian Grid Euler model as a 'mid-fidelity' tool. The projected Phase I will implement and test key modeling and formulation improvements for these methods to enable them to support the design of multi-stage open rotor configurations to meet current and projected performance targets.

A1.05-9471 Physics-Based MDAO Tool for CMC Blades and vanes Conceptual Design

The proposed work will develop a reliability analysis tool consistent with conceptual-level design for ceramic matrix composite (CMC) turbine blades and vanes. The analysis software will comprise a suite of physics-based analysis code modules and NASA's Fast Probability Integrator (FPI). The objective of this analysis tool is to develop optimal material properties, internal and external geometries for a cooled vane/blade using aerothermal, and structural (including creep) analyses. The structural stress analysis will be augmented with a creep module to determine an estimate for part life. The suggested benchmark system problem is a multi-disciplinary analysis of a NASA C3X turbine vane, 2 or 3D versions of the discipline specific models will be taken from the open literature and implemented as plug-in modules for NASA's Open MDAO framework.

A1.05-8776 Advanced Aerodynamic Analysis for Propulsion Airframe Integration

Research in Flight is proposing to develop a fundamentally new, lower order, high fidelity solution approach for the aerodynamic analysis required for engine integration studies. This new approach is based on a new tool known as Flightstream. Flightstream is a surface vorticity-based solver which uses an unstructured surface geometry, and a correlation for skin friction. Research in Flight has demonstrated the capabilities of Flightstream to accurately predict the aerodynamic loads on a range of geometries including high lift configurations. The speed of Flightstream is comparable to traditional panel approaches yet the fidelity in calculating loads has been shown to be comparable to high fidelity CFD solutions. Flightstream has also been configured to operate seamlessly with NASA's Vehicle Sketch Pad (VSP) software. The primary function of the proposed activity will be to develop an automated approach to engine integration by coupling Flightstream with optimization tools, rudimentary engine performance tools, and automated grid generation using VSP. The goals for the optimization will be related to aerodynamic performance and will include lift to drag and moment calculations in consultation with the technical point of contact at NASA.

A1.06-9338 Non-Contact Magnetic Transmission For Hybrid/Electric Rotorcraft

Develops a magnetic transmission (magnetic gearbox) design that will allow optimal matching of high specific power electric motors to efficient propellers for use on electric or hybrid-electric air vehicles. The proposed magnetic transmission will have a mass of no more than an equivalent rated mechanical gearbox. Unlike conventional gears the magnetic transmission will have no lubrication requirements, gear tooth wear, will be immune to vibration fatigue in the gear teeth, and will have minimal acoustic noise. If overloaded the design will benignly "slip a tooth" and then re-engage. Designs, builds and tests a magnetic transmission optimized for specific torque, and compare the weight of the system to an optimal mechanical gearbox of the same power.

A1.06-9851 Vertical Lift by Series Hybrid Power

Develops a reformulated Miller Cycle engine in Series Hybrid Architecture for use in small unmanned vertical lift aircraft to combine the benefits of both direct electric drive and internal combustion engine technology. The reformulated Miller Cycle will also confront the fuel mixing issues associated with UAS sized small engines.

A1.07-9387 High Temperature “Smart” P3 Sensors and Electronics for Distributed Engine Control

Current engine control architectures impose limitations on the insertion of new control capabilities due to weight penalties and reliability issues related to complex wiring harnesses. In collaboration with Air Force Research Lab (AFRL), NASA has been conducting research in developing technologies to enable Distributed Engine Control (DEC) architectures. NASA is particularly interested in these applications for assessing their benefit for the engine system. Compressor discharge pressure measurement has long been a key aspect of turbine engine control to manage stall margin. There is a need for a high-temperature, smart P3 sensor as a key building block for distributed engine controls. The long-term objective of the proposed effort is to advance high-temperature P3 sensor technology for DEC applications through working with OEM partners and industry working groups to: (1) iterate the current technology toward DEC formats/functions, (2) advance the digital electronics design/firmware and high temperature electronics, and (3) present the viability (technical and business case) of the proposed sensor.

A1.07-9813 Variable Fidelity AeroPropulsoServoElasticity Analysis Tool

CFDRC proposes to develop, validate, and demonstrate a variable-fidelity multi-physics framework for AeroPropulsoServoElastic (APSE) simulations of supersonic vehicles. The proposed effort will leverage previously developed AeroServoThermoElastic (ASTE) framework that will be advanced to create an APSE analysis tool for next generation supersonic vehicle simulations. The developed framework will be verified against benchmark cases for accuracy and efficiency. Demonstration of the full capabilities of the technology will be conducted for a representative supersonic transport configuration in a supersonic flow environment. In Phase II, the capability of the framework will be extended by integrating additional NASA and industry preferred computational tools (both high fidelity and reduced order) to the framework. The usability of the framework will be improved by supporting NASA preferred input/output data formats, adding non-linear material models, support for NASA's open Multidisciplinary Design Analysis and Optimization (openMDAO) scripts and further improving the accuracy of the fluid and structure.

A1.08-8885 Miniaturized Dynamic Pressure Sensor Arrays With Sub-Millimeter (mm) Spacing for Cross-Flow Transition Measurements

The proposed concept extends the basic design to high bandwidth, high-spatial resolution, dynamic pressure sensing via reduction in sensor geometry and integration of multiple sensors arrayed on a single chip. The end result is a miniaturized, highly-compact array of dynamic pressure sensors with backside contacts to enable a truly flush-mounted, smooth interface for flow measurement applications.

A1.08-9032 Plenoptic Flow Imaging for Ground Testing

Develops a high-speed, high-resolution plenoptic lightfield flow imaging system to capture a rapid time sequence of simultaneously measured density, velocity and pressure throughout a test volume seeded for laser-induced fluorescence (LIF). The proposed Nanohmics plenoptic flow imager is instantaneous and therefore able to capture rapidly evolving or oscillatory flow phenomena such as turbulence or vortices (unlike existing plane-scanning techniques)

A1.08-9052 Fast Pressure-Sensitive Paint System for Production Wind Tunnel Testing

Develops the continued development of the fast pressure-sensitive paint (PSP) system. To enable real-time data processing, a system composed of a computer with a large block of memory, a multi-core processer, and several high end video cards (GPUs) has been assembled. Modern GPUs include thousands of floating point processors and large blocks of memory which enable parallel computations to be executed on individual images.

A1.08-9770 3D Flow Field Measurements Using Aerosol Correlation Velocimetry

Develops a 3D Lidar Global Airspeed Sensor (3D-GLAS) for remote optical sensing of three-component airspeeds in wind tunnel applications. Conducts a requirements analysis to identify the functional and operational needs of wind tunnel application and of the instrument. A signal link budget analysis tool of the proposed lidar will be developed to aid in instrument design and scaling. A conceptual design of the instrument will be developed, where the system architecture and main components will be identified.

A2.02-9071 A Low Cost, Secure Radio Communications System for UAVs

Sci_Zone, Inc is seeking to develop the LinkStar-AV, an inexpensive, secure, and reliable satellite based radio system for Unmanned Aircraft Systems (UAS). The LinkStar-AV architecture treats the radio system as a secure node on the internet through the GlobalStar satellite communications network, providing continuous coverage between the UAS and ground. Control and monitoring is provided by an adapted version of our QS/Vehicle Management System (VMS), which is used on a range of commercial aircraft and certified under DO-178B (Level D). For the Phase I research program we will develop the prototype of the LinkStar-AV1p hardware, implement a secure link to stream data from the UAS to the QS/VMS ground control station via LinkStar, and develop a prototype of the communications and control software for use on UAS. We will also update QS/VMS ground server and flight software as required to allow it to work with the LinkStar-AV1p radio.

A2.02-9001 Verification and Validation of Adaptive Learning Control System Towards Safety Assurance and Trusted Autonomy

There has been a growing interest in adaptive systems incorporating learning algorithms. Before such adaptive systems can be adopted for use in safety-critical aerospace applications, they must be certified to meet specified reliability and safety requirements. Intelligent Automation Inc. proposes to develop a novel systematic verification and validation framework for adaptive learning flight control systems towards real-time safety assurance and trusted autonomy. A Neural Network (NN) based adaptive controller is designed as an add-on to a previously certified baseline linear controller to enhance robustness to modeling uncertainty and fault-tolerance to system faults. Based on Lyapunov stability theory, an integrity monitoring scheme for the adaptive controller will be developed to detect potential controller malfunctions and unstable learning conditions caused by unanticipated hazardous conditions. In Phase I, the algorithms will be demonstrated using a real-time quadrotor test environment.

A2.02-9371 Human Automation Teaming Testbed for Multi-UAS Management (M-HATT)

Addressing barriers to widespread Unmanned Aircraft Systems (UAS) operations in the NAS is a key goal of NASA research and development (R&D). One barrier is the lack of tools enabling operators to operate multiple UAS with minimal human oversight. This requires a flexible testbed enabling research into key human automation teaming (HAT) areas. We propose to develop a ground station that serves as a Human Automation Teaming Testbed for management of Multiple UAS (M-HATT). M-HATT will facilitate R&D into HAT requirements. In Phase I, we will define M-HATT requirements and create a proof of concept demonstration. In Phase II, we will implement M-HATT software components, and collaborate with NASA HSI researchers to use M-HATT to perform simulation studies and flight tests, and develop a commercialization plan.

A2.02-9479 Fully-Automated, Agricultural Application using Unmanned Aircraft

Interest in civilian use of Unmanned Aircraft Systems (UAS) has increased greatly in recent years. NASA is involved in UAS research that would benefit from advancing the ability of UAS to make real-time decisions based on sensor data with little human oversight. This SBIR effort is designed to develop and demonstrate this capability by executing an onboard system on an existing UAS platform to provide a fully-automated, agricultural application process. Phase I will establish feasibility by demonstrating an ability to perform the required onboard sensing, communication between the UAS and management software, and execution of the software-determined flight path and spraying strategy based on chemical deposition patterns determined by the software for prevailing environmental conditions. Phase II would see the design, development and implementation of the fully-automated system along with a flight demonstration.

A2.02-9594 Mission Planner for Dynamic Precision Based Navigation of Unmanned Aircraft Teams

In this project we investigate and design an innovative system that solves the key problem of multi-vehicle cooperation and interoperability. Our approach is based upon the principles and techniques of Performance Based Navigation (PBN) and Required Navigation Performance (RNP) concepts and is adjusted for other separation, safety, and weather effects. We design the architecture for a system that simultaneously maintains the efficiency and success of a multi-vehicle mission while also detecting and resolving potential loss of separation and conflicts within the NAS. Our primary technical objectives are: i) Demonstrate a common set of flight path planning parameters built using PBN and other constraints enabling UA to interoperate and cooperate as a team; ii) Produce an algorithmic software approach that selects a best fit flight path set for a UA team mission that involves heterogeneous UAs; and iii) Show that the planners can respond to conformance monitoring needs for re-planning and contingencies. The project includes a feasibility demonstration and human factors research into the display of optional trajectory sets for the UA team.

A2.02-9727 A Modular Swarm Optimization Framework Enabling Multi-Vehicle Coordinated Path Planning

The advancement of Unmanned Aerial Systems (UAS) with computing power and communications hardware has enabled an increased capability set for multi-vehicle collaborative operations. Heron Systems proposes the Multi-Agent Cooperative Engagement (MACE) framework that enables

collaborative resource allocation, task allocation, and path planning for unmanned systems operating in dynamic environments subject to diverse communication conditions. This Phase I work will focus on the path planning portion of MACE. The path planning architecture will define key modules to plan paths to a global objective, assess potential obstacles, and avoid collisions. At the conclusion of Phase I, the MACE path planning capability will be demonstrated using Heron Systems' previously developed flexible UAS simulation suite and ISAAC software, promoting high fidelity hardware-in-the-loop simulation/stimulation testing with COTS hardware components.

Appendix B.—Fiscal Year 2014 Phase II Contract Abstracts

A2.01-8766 ASPECT (Automated System-level Performance Evaluation and Characterization Tool)

Scientific System Company has developed a suite of SAA tools and an analysis capability referred to as ASPECT (Automated System-level Performance Evaluation and Characterization Tool). ASPECT encapsulates our airspace encounter generator, sensor/tracker fusion algorithms, and prediction, threat assessment, and avoidance modules. It also provides both component-level and system-level analysis that is required for evaluating how well SAA sensors and software meet fundamental safety requirements for UAS in the NAS. Phase II will: (i) Expand and validate the underlying sensor models and demonstrate capability using flight test data generated at Olin College (Needham, MA), (ii) Extend our REACT system, and (iii) Carry out SAA system-level analyses using ASPECT to illustrate the relationship between sensor suite (hardware) selection, component SAA software modules, and achievable safety performance of the integrated system.

A2.01-9144 UAS Demand Generator for Discrete Airspace Density

The UAS Demand Generator for Discrete Airspace Density (UAXPAN) is a cloud-based application producing UA demand forecasts from user defined scenarios consisting of: UAS, industry, missions, and forecast elements. In Phase I, UAXPAN was developed as a prototype to demonstrate government and commercial UAS operations. In Phase II, the overall project objective is to enhance the UAXPAN system to allow users and governance groups to start actively adding UAS missions, forecasting UAS growth, and assessing the impact of UAS operations in different areas. The collected data can then be shared with other users seeking to perform assessments of impact or demand and to optimize the crowd sourced input in a cloud-based hosting approach to receive feedback.

A2.01-9219 SOAR - Stereo Obstacle Avoidance Rig

Opto-Knowledge Systems, Inc. (OKSI) and Professor Frank Dellaert of Georgia Institute of Technology are teaming up to develop a low cost passive low-SWaP spherical situation awareness sense/avoid system based upon monocular stereo vision (i.e., stereo-from-motion) for small UAS platforms operating within the NAS. When flying close to the ground, obstacles such as cars, trees, buildings, and so on are not equipped with beacons. In this setting, the ability to actively detect obstacles within the environment in real-time and to take evasive maneuvers to avoid collisions is a required capability for safe operation in the NAS. Currently, there are no existing technologies that sufficiently address the sense/avoid problem associated with operation of small UAS platforms (<55lbs) operating within the NAS. To this end, OKSI is developing the Stereo Obstacle Avoidance Rig (SOAR) that will provide a complete solution to the sense/avoid problem for small UAS platforms. The SOAR system utilizes a video stream from a distributed aperture array of cell phone cameras combined with state-of-the-art single-camera stereo vision algorithms in order to construct accurate 3D environmental maps in real-time.

A2.01-9239 UAS Power Amplifier for Extended Range of Non-Payload Communication Devices (UPEND)

The high-efficiency and linear UPEND RF C-band power amplifier was designed, simulated and partially prototyped in Phase I. UPEND leverages state-of-the-art analog pre-distortion linearization and

Doherty power amplifier circuits, MMIC technology, and module-level power efficiency and thermal design, to minimize size, weight, and power consumption (SWaP) of the connectorized PA module, while maintaining the linear output required by amplitude modulation. In Phase II NuWaves will address the needs of both amplitude-modulated and constant-envelope waveforms by developing multiple MMICs and packaging them together as needed. Separate die will be fabricated for the Doherty amplifier and the linearizer circuits, wire bonded and packaged into two different component-level integrated circuits – one with and one without the linearizer. Two different connectorized PA module variants will be developed using these two component-level ICs, adding the necessary power supply circuitry, supporting circuitry, and mechanical and thermal design to address different NASA and commercial market needs.

A2.01-9452 A Compact, Wide Area Surveillance 3D Imaging LIDAR Providing UAS Sense and Avoid Capabilities

The Phase II effort will complete the design of a flight prototype of an eye safe 3D LIDAR which, when deployed on Unmanned Ariel Systems (UAS), will detect aircraft flying near the UAS and enable timely avoidance maneuvers. The Active Continuous Awareness Surveillance System (ACASS) sensor detection range for small air vehicles is 5 km. ACASS searches a 30 degree elevation by 360 degree azimuth field of regard in three dimensions every 2 seconds. ACASS key components include a SWIR, high pulse rate fiber laser, optical beam shaping and elevation steering elements, an advanced focal plane array with integrated readout electronics, a wide field of view receiver telescope, and mechanical elements for azimuth scanning. These elements will be developed, tested, and integrated into an Engineering Development Model. Test results will be used to update the final design of the flight prototype.

A2.01-9910 Non-Parametric, Closed-Loop Testing of Autonomy in Unmanned Aircraft Systems

The proposed Phase II program aims to develop new methods to support safety testing for integration of Unmanned Aircraft Systems into the National Airspace (NAS) with a particular focus on testing the collision avoidance (CA) algorithms of a UAS Sense-and-Avoid (SAA) system. This research addresses the fundamental difficulty of verifying the performance of autonomous systems that dynamically react to the environment. In particular, this research program would develop novel methods for conducting non-parametric, closed-loop simulation testing of collision avoidance algorithms as well as other autonomous operations. The technology generates a campaign of simulation experiments that automatically adapt to the algorithms in question. The purpose of this innovation is to expose potential vulnerabilities in UAS autonomy that are generated through the interaction of autonomous UAS algorithms with other agents such as an intruding aircraft operating under ``right of way rules''. This work augments both the probabilistic open-loop testing methods, where agents do not react, and closed-loop testing where agent behavior is fixed a priori.

A3.02-9794 Phased Array Technique for Low Signal-To-Noise Ratio Wind Tunnels

Noise measurement of aerospace vehicles is difficult and usually requires expensive, specialized facilities. With the proliferation of UAVs there is need for noise data, both for ISR and non-military vehicles. Wind tunnel testing is common and much less expensive. The innovation is a novel in-flow microphone array combined with the start of the art Functional Beam-forming algorithm that makes it practical to measure UAV noise in a non-acoustic wind tunnel. The proposal calls for further development

of the measurement technique so that it can be commercialized as a service using the Kirsten Wind Tunnel at the University of Washington.

A3.03-9123 Compact Kinetic Mechanisms for Petroleum-Derived and Alternative Aviation Fuels

To be useful for computational combustor design and analysis, tools like the National Combustion Code (NCC) must be sufficiently compact so that they can be utilized in computational fluid dynamics (CFD) simulations. Despite advances in CFD, appropriate kinetic mechanism reduction for kerosene-range fuels and significant combustion property variation among certified fuels remains a challenge for CFD-advised design of high pressure, low-emissions combustors. The proposed project will produce and demonstrate a meta-model framework for automated generation of fuel-flexible compact chemical kinetic mechanisms appropriate for 3-D combustion CFD codes.

A3.05-8588 Physics-Based Conceptual Design Tools

Streamlines the structural layout process, improve the overall user experience, and develop a comprehensive suite of capabilities in an effort to build a complete weight statement for unconventional (and conventional) conceptual wing and fuselage designs. The main goal for this effort will be to develop a software tool capable of generating weight and load responses for unconventional designs from physics-based structural analysis simulations.

A3.06-9367 Hybrid-Electric Rotorcraft Tool Development, Propulsion System Trade Space Exploration, and Demonstrator Conceptual Design

Hybrid-electric propulsion is becoming a widely accepted technology for aircraft that can provide significant reduction in fuel consumption. The majority of the analysis tools that exist today, however, do not harness the capability to analyze these unique systems. The Phase I effort focused on the development of the PANTHER tool in preparing it for modeling hybrid and all-electric rotorcraft. The goal of the proposed Phase II effort is to further improve upon the strengths of the PANTHER code that was developed, and then utilize this tool to further explore the hybrid-electric rotorcraft design space. The tool will be expanded with modules for fuel cells and flywheels along with improved engine modules, physics-based motor and drive models, and a new capability to model complete missions. The thermal management aspect will also be addressed with modules for radiators, cooling ducts, fluids, and pumps. Using the results and lessons learned from these studies, a detailed conceptual design will be performed on a notional hybrid-electric rotorcraft demonstrator.

A3.06-9495 Hybrid Electric Propulsion System for a VTOL/Multirotor Aircraft

LaunchPoint Technologies proposes to build a scalable hybrid electric propulsion system. LaunchPoint will build and fly a 1 kW hybrid electric vehicle and will build and bench test a 6 kW hybrid power source to demonstrate scalability to much larger systems. Using Fly-By- Wire techniques and applying it to electric aircraft propulsion can lead to highly reliable architectures which we call "Propulsion-By-Wire", providing a tremendous increase in reliability and safety of the vehicle compared to conventional VTOL architectures. In this Phase II we propose to develop the hybrid power source (Battery, BMS, Gen-set, and hybrid controller) portion of a "Propulsion-By-Wire" system for 2 power levels. LaunchPoint will build and fly a 1 kW hybrid electric vehicle that will meet notional airworthiness

requirements for flight over people, and will scale the hybrid power source to 6kW proving the potential scalability of the system.

A3.07-8783 Robust High Temperature Environmental Barrier Coating System for Ceramic Matrix Composite Gas Turbine Components using Affordable Processing Approach

Research is proposed to demonstrate the use of advanced manufacturing techniques to enable the affordable application of multi-functional thermal/environmental barrier coatings (T/EBCs) having enhanced resistance to high temperature combustion environments. T/EBCs are envisioned to protect the surface of Si-based ceramics against moisture-assisted, oxidation-induced ceramic recession. One approach to increase the temperature capability of these systems is the incorporation of multilayered T/EBC designs. In this effort, enhanced processing techniques will be employed to demonstrate the manufacture of robust T/EBC systems using a physical vapor deposition based processing approach which enables improved coating adhesion and advanced coating architectural, compositional, and microstructural control, as well as non-line-of-sight (NLOS) deposition. During this proposed Phase II effort, processing/property/performance relationships for the manufacture of the novel coating architectures will be determined. Optimized processing approaches will then be used to demonstrate the deposition of high temperature capable T/EBC systems coating onto components of interest to gas turbine engine manufacturers.

A3.07-9218 Cavitation Peening of Aerospace Bearings

High-value bearings are a critical part of the safety, reliability, cost and performance of modern aircraft. A typical passenger jet will have 100 to 175 high-valve bearings costing from $2,500 to $50,000 each for a total aircraft cost of $300,000 to $600,000. Any process that increases bearing performance and reliability will have a commensurate effect on aircraft safety, reliability, performance and operating cost. In Phase I, Ormond demonstrated a novel surface enhancement process, cavitation peening, imparting deep, high magnitude residual stresses that are predicted to significantly enhance bearing life, reliability and performance. Preliminary fatigue results generated in Phase I look promising and analytical results indicate a fatigue life improvement of over 100% may be possible. Cavitation peening uses ultra-high pressure water jets to generate intense clouds of cavitation bubbles that collapse on the work piece generating shock waves that cold work the material. The proposed Phase II work would refine the process, address readiness level issues and generate the fatigue data that is critical to wide spread acceptance of the cavitation peening technology.

A4.01-8744 Oxygen-Independent Pressure Sensitive Paint

Pressure sensitive paint (PSP) systems are excellent tools for performing global pressure measurements in aerodynamic testing. The major limitation of PSP for pressure mapping is its dependence on an oxygen-containing flow, since those paints are actually oxygen sensors. Intelligent Optical Systems (IOS) is developing a unique coating in which fluorescence quenching can form high resolution images of the true pressure distribution on surfaces in transonic flow in oxygen-free atmospheres. In Phase I, IOS has created the oxygen-insensitive pressure-sensitive coating materials, and applied them to glass and stainless steel test coupons. The fluorescence emission lifetime and intensity of these test samples were measured at varying static pressures under pure nitrogen, showing significant correlation with pressure in the range studied (from 0.05 to 14.7 psi), and excellent repeatability. This sets

the stage for Phase II development and delivery of a complete temperature-compensated true ambient pressure sensitive paint system that can be used to characterize flow around structures in hypersonic wind tunnels. At the end of Phase II, the coatings will have been tested at relevant environments (TRL5), and will be available for NASA to begin testing in a high-fidelity laboratory environment (TRL6).

A4.01-8764 Versatile Sensor for Transition, Separation, and Shock Detection

The proposed innovation is a simple, robust, self-contained, and self-powered sensor array for the detection of laminar/turbulent transition location, areas of flowfield separation, and shock wave locations. The system can be used for both flight test and in ground test facilities. The proposed system uses a robust and proven sensor technology combined with a novel mounting and manufacturing technique. The sensor array is reusable and requires no calibration, external power source or acquisition system. The system combines an array of small, surface flush, sensors embedded in a thin, flexible polyimide strip coupled with a self-contained, battery powered acquisition, reduction, and storage system. The system operates by sensing changes in local heat transfer within the boundary-layer. Variations in heat transfer due to the state of the boundary layer (laminar, transitional, turbulent, separated regions) produce changes in the sensor output. The system will be quantitatively accurate across the low-speed through supersonic flow regime. After testing, the system can be quickly removed and reused.

A4.01-9539 Development of a “Digital Bridge” Thermal Anemometer for Turbulence Measurements

Thermal anemometry has been a key experimental technique in fluid mechanics for decades. Due to the small physical size and high frequency response of the sensors, the technique has been used for studies of turbulent flows. Hot wire anemometry is uniquely capable of extremely high frequency response and fine spatial resolution measurements. ViGYAN has demonstrated a fundamental change to the anemometer configuration. First, the circuitry to power the sensor is packaged immediately adjacent to the sensor, removing the effect of the cable connecting the sensor to an external anemometer. Second, modern analog-digital conversion hardware has been employed to the maximum extent possible. Based on these results, the Phase II work will deploy this "Digital Bridge" system using a Digital Signal Processing (DSP) device connected via fiber-optic cable. A production-ready version will be developed and delivered; facilities, expertise, and resources are available to fabricate and deliver production units at the conclusion of Phase II. Production designs for ruggedized units will also be done for use in wind tunnels that operate at higher dynamic pressures and extreme temperatures.

A4.01-9869 High Temperature Fiberoptic Thermal Imaging System

A prototype high temperature, single optical fiber thermal imaging system will be developed, tested, and delivered to GRC. The components of the instrument will be specified in detail, designed, fabricated, and purchased where appropriate. The illumination and imaging system will be assembled and system tests will be performed. Given a set of calibration images produced by the diagnostic, the image analysis needed to recover a thermal image of a surface will be developed and demonstrated. System resolution tests will be performed. The thermal imaging laboratory system will be modified to be appropriate to a prototype commercial instrument. The thermal imaging prototype will be tested and debugged at Thoughtventions and its operating characteristics defined.

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